# Design of a movement corridor for the Green and Golden Bell Frog *Litoria aurea* at Sydney Olympic Park

**Glenn W. Muir**

Biosis Research Pty Ltd, 15-17 Henrietta Street, Chippendale, NSW, 2008
Present address: Australian Museum Business Services (AMBS), 6 College St, Sydney, NSW, 2010
email: Glenn.Muir@austmus.gov.au

## ABSTRACT

In 2005 the Sydney Olympic Park Authority proposed a development involving the adaptive re-use of the Newington Armory Wharf, on the southern bank of the Parramatta River. The development site was located between areas of known habitat for the endangered Green and Golden Bell Frog *Litoria aurea*. The development proposal included features that might reduce the potential for *L. aurea* movement between these habitats, including the construction of a road to the wharf, a car park south of the wharf and the replacement of some areas of tall native grass with mown turf to create a picnic area overlooking the river.

A site assessment, a review of published and unpublished literature, and an examination of data collected at Sydney Olympic Park regarding movements and colonisation of constructed habitat by *L. aurea* were carried out. Features that may assist the dispersal of the frog between the known habitat areas were subsequently incorporated into the development along two "habitat corridors". These features included six ponds of varying dimensions and measures to promote areas of open grassland. A need for research and publication of data regarding movement and dispersal in this species was identified.

Key words: *Litoria aurea,* Green and Golden Bell Frog, Sydney Olympic Park, movement corridor, habitat corridor

## Introduction

The provision or maintenance of habitat linkages may be of significance to the long-term viability of the endangered Green and Golden Bell Frog *Litoria aurea.* In New South Wales (NSW), which makes up over 90% of the species' known distribution (Cogger 2000), *L. aurea* appears to be restricted to 54 coastal locations and a single location in the Southern Tablelands (White and Pyke 2008), many of which are isolated from one another. A genetic study of *L. aurea* over a 1,000 km range (Burns *et al.* 2004) found a highly significant relationship between genetic differentiation and geographical distance for most sampled locations, but detected no significant association in those areas where *L. aurea* populations persist in continuous habitat (the south coast of NSW and north-eastern Victoria). The study concluded that maintaining areas of continuous habitat is critical to the long-term conservation of the species and management should focus on the protection of local populations and habitat to promote connections between populations.

Maintaining habitat linkages may also be important to the conservation of *L. aurea* at a local scale. The ability to occupy and move between several breeding sites may assist isolated populations of *L. aurea* to recover from catastrophic events such as drought or outbreaks of pathogens such as the chytrid fungus *Batrachochytrium dendrobatidis* (Penman *et al.* this issue). Thirty of the 43 populations listed in the draft recovery plan for *L. aurea* are described as comprising two or more sub-populations, many of which have tenuous interconnectivity and at risk of being lost through stochastic incidents and ongoing threatening processes (DEC 2005). At least nine locations previously occupied by small, isolated populations of *L. aurea* may have suffered local extinction in the last 10 years (A. White, pers. comm.).

This paper describes the process used to design a movement corridor for an urban population of *L. aurea*. The corridor was a response to a new development situated between areas of known habitat for the species. Features of the design and information regarding the movement of *L. aurea* in Sydney Olympic Park are presented.

## Study area

Sydney Olympic Park is located approximately 10 km west of the Sydney CBD. It is enclosed by urban or industrial development on three sides and the Parramatta River on the fourth (northern) side. It contains a range of landscapes, including remnant woodland and wetland, stands of mangrove, planted grassland and forest, mown turf and playing fields, entertainment and sporting facilities, roads and car parks. The estuarine Haslams Creek crosses the site from south-west to north-east.

The three main areas of recorded *L. aurea* activity within Sydney Olympic Park are: a former shale and sandstone quarry known as the Brickpit; adjoining areas to the north of the Brickpit known as Kronos Hill and Wentworth Common, which contain a series of constructed ponds and wetlands distributed throughout planted native grasslands, mown turf and playing fields; and a 12 ha freshwater wetland known as Narawang Wetland (SOPA and AMBS 2002) (Fig. 1). The species has also been recorded in several locations outside of these areas, including the Wharf Pond and Wilson Park Wetland along the Parramatta River foreshore (Muir, pers. obs; K. Darcovich, pers. comm.) (Fig. 1).

The focus of this study is an area of Sydney Olympic Park known as Blaxland Common, located along the foreshore of the Parramatta River between the Newington Armory, Wilson Park and the Silverwater Correctional Facility (Fig. 1). Prior to the 2000 Olympic Games, Blaxland Common was a waste disposal site known as the Auburn/Hardies tip. The Newington Armory Wharf on the foreshore east of Blaxland Common was used for the transport of materials to the Armory. The tip area was remediated and transformed into a raised clay-capped mound covered with mown turf, with bitumen paths and car parking areas sited around the perimeter. The slopes of the mound and Parramatta River foreshore were planted with stands of native grasses, shrubs and small trees.

## Proposed development and legislative requirements

In 2005, the Sydney Olympic Park Authority (SOPA) submitted a concept plan under Part 3A of the NSW *Environmental Planning and Assessment Act 1979* for the adaptive re-use of the Newington Armory Wharf, the construction of a road through Blaxland Common to the wharf, the creation of a car park and turning circle south of the wharf and the establishment of picnic areas overlooking the river. The Director-General's requirements provided by the NSW Department of Planning included a requirement for information regarding *L. aurea* corridors and proposed mitigation measures. The concept plan required compliance with the SOPA *Parklands Plan of Management* (PoM), which states that a local objective for Blaxland Common is to provide supplementary Green and Golden Bell Frog habitat. An ecological assessment was prepared (Biosis Research 2005) and supplementary information regarding a proposed bell frog corridor was provided to the consent authority.

## Assessing the need for a corridor

The first step in the process was to establish whether a corridor was needed. This was assessed on the basis of a review of records of *L. aurea* in nearby habitat, current and historical land use, and published and unpublished information regarding the movement of *L. aurea.* There were no data to confirm whether or not *L. aurea* dispersed across Blaxland Common, either currently or historically. Five spotlight surveys carried out at the site in March 2006 did not detect *L. aurea*, although individuals of the species were readily detected in other parts of Sydney Olympic Park on three of those occasions (Muir, pers. obs; T. English, pers. comm.).

Data were available to confirm that *L. aurea* had been detected in areas to the east and west of Blaxland Common. A brackish waterbody known as the Wharf Pond is located within the Newington Nature Reserve near the eastern boundary of the site (Fig. 1). *Litoria aurea* was first detected at the Wharf Pond in 1993 (Greer 1994), was heard calling in October 2006 (Muir, pers. obs.) and had been heard calling on a number of occasions in the intervening years (P. Straw, pers. comm; AMBS 2003, 2004, 2005). A depression known as the Wilson Park Wetland is located adjacent to the western boundary of the site. The Wilson Park Wetland collects runoff from the Silverwater Correctional Facility and is covered with a thick stand of rushes (mainly *Typha* sp.). Two *L. aurea* were heard calling in the Wilson Park Wetland in February 2004 (AMBS 2004) and a single calling male was heard during the summer of 2004/2005 (K. Darcovich, pers. comm.).

The species was also observed in pools and waste treatment ponds in Wilson Park during the spring and summer of 1999/2000 (Muir, pers. obs.), which have since been removed as part of site remediation. Seventeen *L. aurea*

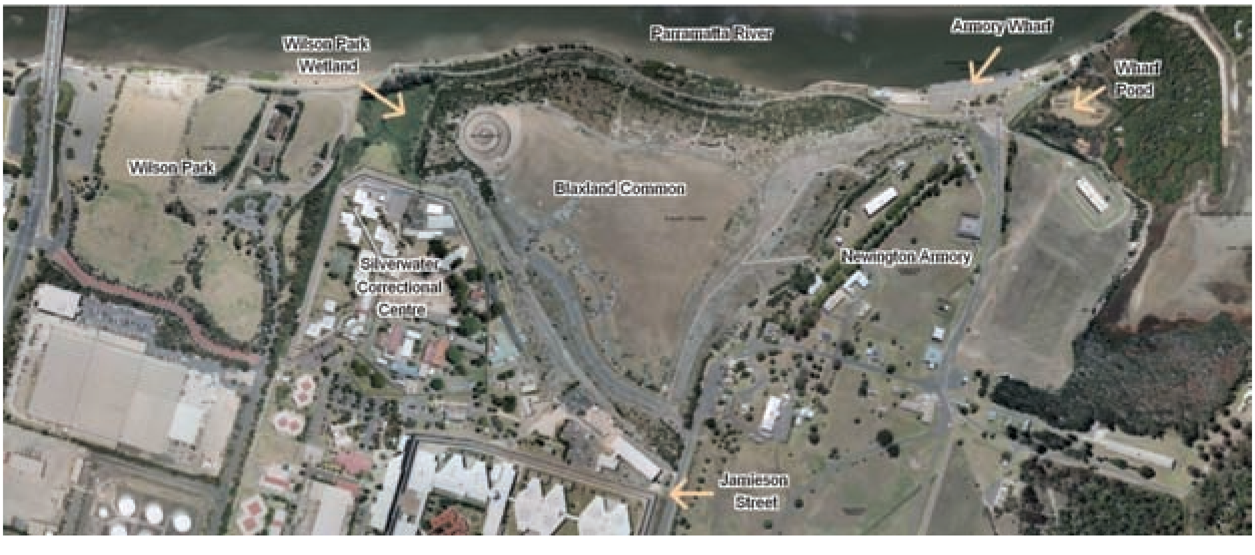

**Figure 1**. Blaxland Common prior to the development

individuals were removed from the site and placed in the Wilson Park Wetland (AMBS 2000) as part of an impact mitigation strategy proposed by Mount King Ecological Surveys for the remediation works (Perram & Partners 1999). The status of *L. aurea* in Wilson Park is currently unclear; the site currently contains some constructed ponds used for bioremediation, but the species has not been detected during recent auditory surveys (K. Darcovich, pers. comm.).

A population of *L. aurea* also occurs within the Clyde Oil Refinery, on the western side of Duck River. The size and status of the refinery population is unknown; however, breeding has been observed in stormwater detention basins at this site (pers. obs.), 16 individuals were recorded in 2001 (White and Pyke 2008) and *L. aurea* has been observed by refinery staff as recently as 2004 (A. White, pers. comm.).

Evidence from mark-recapture studies shows that *L. aurea* individuals are capable of movement over the distance between the Wharf Pond and the Wilson Park Wetland (approximately 800 m), and the Wilson Park Wetland and the Clyde Oil Refinery (also approximately 800 m). Data from a mark-recapture program at Sydney Olympic Park show three movements over 700 m, including two more than 1 km (AMBS 2000, 2002). Hamer (2002) reports dispersal of up to 1 km, Goldingay and Newell (2005) reported the recapture of a single individual over 1.2 km from its capture site and Pyke and White (2001) reported recaptures "up to 2-3 km between successive capture locations".

Movements by bell frogs of the magnitude indicated above appear to be rare. Both Christy (2001) and Hamer (2002) reported that the majority of recorded *L. aurea* movements were within or between closely spaced water bodies or groups of water bodies. This is consistent with data from the *L. aurea* mark-recapture program at Sydney Olympic Park, which indicate that most recaptures are within the same pond or nearby ponds. Longer-range movements recorded at Sydney Olympic Park were all within the Brickpit, Narawang Wetland or the Kronos Hill / Wentworth Common areas, with no recorded movements between them.

Hamer (2002) showed that most of the water bodies where *L. aurea* persisted at Kooragang Island were either a source pond or located within 50 m of a source pond and that unoccupied water bodies or water bodies where the species did not persist were isolated from other occupied water bodies by a distance of over 500 m. He concluded that movement of *L. aurea* was most likely to be hampered by distance rather than physical barriers, and that if intervening water bodies are destroyed it may cause more isolated water bodies to be become permanently unoccupied. This is supported in part by the evidence of Goldingay and Newell (2005), who reported that no movements at all were recorded between two breeding ponds approximately 500 m apart, although there were no apparent physical barriers to dispersal in between.

Evidence also suggests that *L. aurea* are capable of movement over a range of substrates. Hamer (2002) recorded *L. aurea* moving across an estuarine creek and a railway and Goldingay and Newell (2005) recorded movements across roads and possibly residential gardens. AMBS (2002) reported six movements from one side of a road to another, either by crossing the road or using underpasses. In Sydney Olympic Park the species has been observed climbing fences (Christy 2001) and active at night on bare rock, mown turf and long grass (pers. obs.).

However, while *L. aurea* individuals have been observed crossing a variety of substrates, the presence of suitable shelter habitat may improve the survival of individuals moving between habitats. Hamer (2002) postulates that movement between water bodies represents a cost in terms of increased risk of predation and increased energy expenditure. Christy (2001) found that distances moved at Kurnell were greater than distances moved at the Brickpit and suggested greater continuity of suitable habitat at the latter location as the most probable explanation. Christy (2001) also stated that her radio-telemetry results suggest green and golden bell frogs "sought cover while moving, either in long grass, under rocks or by 'shelter-hopping'" and that direct migration paths that have been observed in other amphibian species were not evident for *L. aurea*.

Habitat for *L. aurea* was created in the areas of Sydney Olympic Park known as Kronos Hill and Wentworth Common between 1995 and 2000 in accordance with a management plan for *L. aurea* (AMBS 1999; Darcovich and O'Meara 2008). The area has similarities to Blaxland Common, in that it is an entirely constructed landscape of playing fields and turf-covered mounds with areas of planted native grasses and trees covering the slopes of the mounds. Large freshwater wetlands and groups of ponds were constructed in the lower parts of the area. These were linked by grassy corridors containing smaller "stepping-stone" ponds.

Mark-recapture data collected by the *L. aurea* monitoring program at Sydney Olympic Park prior to and following the year 2000 indicate that *L. aurea* movement occurred throughout Kronos Hill and Wentworth Common, as well as other areas of the Park where continuous habitat or corridors occurred or had been created (AMBS 2002). Individuals of the species (marked and unmarked) were detected at least once in almost every created pond, often within a few months of pond excavation. While these data do not indicate whether frogs preferentially use such corridors, they do show that bell frogs are capable of moving through them.

On the basis of information regarding movements of *L. aurea*, the location of known habitat, the removal of ponds during earlier remediation works and the reduction in potential shelter habitat represented by the proposed development, it was considered that the establishment or enhancement of potential "corridor habitat" in Blaxland Common would be likely to be of benefit to the *L. aurea* population and may mitigate against impacts of the proposed development on this species.

## Site assessment

The second step involved an examination of the topography, drainage patterns, vegetation, substrate, existing land use and proposed future land use at the site. The site assessment found no areas where water would pool for more than a few hours or days after heavy rain. The greater part of the site was mown turf that contained no potential shelter sites for *L. aurea*, and a large proportion of the areas that contained planted native grasses and trees were being replaced by a dense monoculture of Swamp-oak *Casuarina glauca.*

The examination also identified a north-south drainage line located along the western side of the Newington Armory that could be readily modified to provide potential habitat for *L. aurea*. An east-west drainage line along the northern perimeter of the Silverwater Correctional Centre already contained a few small ponds and a broad open grassland area. The most direct route between the Wharf Pond and Wilson Park Wetland (along the foreshore of the Parramatta River) contained stands of grasses and sedges that could provide shelter for dispersing frogs.

The main limitations to the development of a movement corridor were identified as topography and the proposed land use associated with the development application. The north-south and east-west drainage lines did not meet and would be further separated by a road, and any proposed corridor along the foreshore would necessitate frog movement across the busiest part of the site, that would contain both vehicle and pedestrian hubs.

## Corridor design

The limitations and opportunities presented by the site and documented research on *L. aurea* movement suggested the strategy of a twin corridor design for Blaxland Common.

### Component one – provision for short-range movement

The first component involved the construction of a series of ponds to provide potential *L. aurea* habitat along the north-south drainage line on the western side of the Armory, including at least one potential breeding pond. Smaller, "stepping-stone ponds" were established between the north-south drainage line and the east-west drainage line along the northern perimeter of the Silverwater Correctional Centre. The intention of this component was to reduce the distance between Wilson Park and the nearest potential source pond and to provide a series of smaller, stepping-stone ponds to reduce the distance between water bodies. The location of the ponds is shown in Figure 2.

### Component two – provision for long-range movement

Observations of *L. aurea* at Sydney Olympic Park suggest that the occurrence of particular climatic conditions enables the species to move considerable distances to temporarily occupy, and sometimes breed in, a variety of water bodies that would not typically be utilised under different circumstances. After heavy rain in summer the frogs have been observed or heard calling from locations such as shallow puddles in grass, water-filled wheel tracks, mangroves and brackish ponds, sites where it has rarely (or never) been recorded at other times (pers. obs.). Hamer (2002) describes similar occurrences at Kooragang Island, where males moved up to 1 km to congregate and call for brief periods in "satellite" habitats after heavy rain.

The aim of the second component was to enhance potential shelter for *L. aurea* individuals that may undertake long-range movements along the foreshore, without encouraging short-range movements across the Armory Wharf car park. It was considered preferable not to provide ponds and other habitat that might encourage frogs to occupy and move around sites close to vehicle activity. However, it was assumed that frogs were likely to cross this area anyway, under good (i.e. wet) weather conditions. This component involved the construction of a single pond approximately half-way between the Wharf Pond and the Wilson Park Wetland and the provision of an area of open grassland and sedge along the foreshore (Fig. 2).

### Grassland linkages

It was assumed that suitable corridor habitat is most likely to consist of open, grassy areas, particularly those situated along drainage lines or other moist areas. Christy (2001) indicated that *L. aurea* at Sydney Olympic Park and Kurnell avoided areas of dense, shrubby vegetation in preference for low grassy and herbaceous cover. Pyke *et al.* (2002) surveyed numerous *L. aurea* sites across Australia and New Zealand and found that features common to terrestrial environments where *L. aurea* still occur were limited shading and high levels of disturbance, with nearby terrestrial habitats including bare ground, grassland and forest, although at some sites shrubland or woodland was present.

The corridor design therefore includes the establishment and maintenance of open grassland linkages between all pond sites. In some areas this involves the control of *C. glauca*, in order to encourage a grassy understorey. It is important to note, however, that there is currently no evidence to indicate that *C. glauca* is in itself a barrier to the movement of *L. aurea*.

### Other measures

Movement corridors in some locations have involved the use of underpasses and frog exclusion fencing. However, in order to be effective an underpass would require the provision of frog exclusion fences along the full north-south extent of Blaxland Common. Such fences would limit the movement of *L. aurea* to those individuals that find their way to an underpass. Blaxland Common presents a situation where the need to facilitate frog movement may outweigh the potential mortality that may be incurred by animals crossing roads, and where the provision of alternative measures (appropriate signage, speed restrictions after dusk) to reduce or minimise such mortality is feasible. An alternative proposal to install

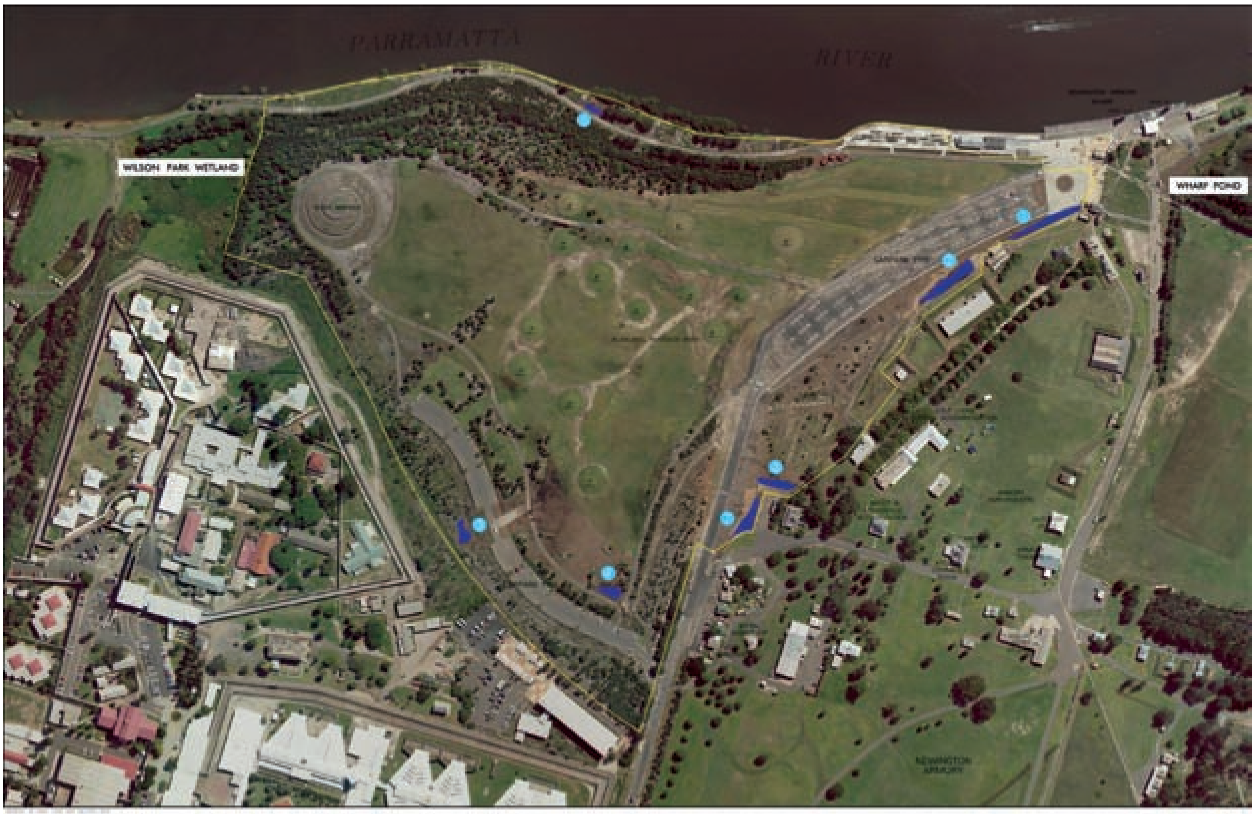

**Figure 2.** Blaxland Common subsequent to the development

cattle grids beneath the road was discarded, as it was considered that *L. aurea* may use the top of the cattle grids as perch sites.

The development does, however, incorporate measures aimed at deterring frogs from entering areas of high vehicle movement near the Armory Wharf. This will involve the construction of a vertical concrete edge approximately 60 cm in height between the north-south drainage line and roadways in this area.

## Monitoring

Monitoring of *L. aurea* has been carried out at the Wharf Pond since 2001 and the Wilson Park Wetland since 2002. The monitoring program includes two surveys for calling frogs carried out between November and January each year. The monitoring project was extended to include the ponds constructed in Blaxland Common in 2007. The monitoring is part of a broader strategy examining the distribution of *L. aurea* at Sydney Olympic Park over time and the data collected should indicate whether or not continued occupation of the Wilson Park Wetland, Blaxland Common and the Wharf Pond is occurring.

Monitoring in December 2007 detected 12 calling *L. aurea* distributed across four of the new Blaxland Common ponds (ponds 3, 5, 6 and 7) and six calling *L. aurea* in the Wharf Pond.

## Conclusion

Given the limitations of the existing habitat and the removal of ponds in Wilson Park in 2000, it is hoped that the installation of the movement corridor features described herein will increase rather than decrease the potential for *L. aurea* movement between the Wharf Pond and the habitats to the west. This may assist in the conservation of the species at this site by maintaining its current range. The presence of the species in this area will continue to be monitored.

It is important to note that the corridor design presented here is based upon assumptions as well as published and unpublished data. While this paper provides a process for developing a corridor design within an urban location, each situation will have its own unique values and requirements. It is not the intention of this paper to provide a recipe to be used in every location. There are a number of aspects of the movement behaviour of *L. aurea* that require further research.

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## Acknowledgements

The impact assessment and corridor design was a commission undertaken by Biosis Research and funded by the Sydney Olympic Park Authority. The concept design for Blaxland Common was produced by Hargreaves & Associates. Phil Goodwin, Kerry Darcovich and Jim Stone provided valuable information regarding the site. Emma Burns, Hal Cogger, Kerry Darcovich, Elizabeth Magarey, Cate McElroy, Charles Meredith, Trent Penman and Fiona Powell provided comments on the original manuscript. An anonymous referee and Ross Goldingay provided comments that considerably improved the manuscript. Robert Suansri assisted with the figures.

## References

**AMBS 1999.** Management plan for the green and golden bell frog *Litoria aurea* at Homebush Bay. Prepared by Australian Museum Business Services for the Olympic Co-ordination Authority.

**AMBS 2000.** Monitoring the green and golden bell frog at Homebush Bay: annual report June 1999 – May 2000. Prepared by Australian Museum Business Services for the Olympic Co-ordination Authority.

**AMBS 2002.** Population size estimation for the green and golden bell frog at Homebush Bay 2000 - 2001. Prepared by Australian Museum Business Services for the Olympic Co-ordination Authority.

**AMBS 2003.** Monitoring the green and golden bell frog at Sydney Olympic Park: annual report June 2001 – June 2002. Prepared by Australian Museum Business Services for the Sydney Olympic Park Authority.

**AMBS 2004.** Green and golden bell frog monitoring at Sydney Olympic Park: annual report July 2003 – June 2004. Prepared by Australian Museum Business Services for the Sydney Olympic Park Authority.

**AMBS 2005.** Green and golden bell frog monitoring at Sydney Olympic Park: annual report July 2004 – June 2005. Prepared by Australian Museum Business Services for the Sydney Olympic Park Authority.

**Biosis Research 2005.** Flora and fauna impact assessment: Blaxland Common & Newington Armory Wharf redevelopment concept design. Prepared by Biosis Research Pty. Ltd. for the Sydney Olympic Park Authority.

**Burns, E.L., Eldridge, M.D.B. and Houlden, B.A. 2004.** Microsatellite variation and population structure in a declining Australian Hylid *Litoria aurea. Molecular Ecology* **13**: 1745-1757.

**Christy, M.T. 2001.** The ecology and conservation biology of the green and golden bell frog *Litoria aurea* (Lesson 1829) (Anura: Hylidae). PhD thesis, University of Sydney.

**Cogger, H.G. 2000.** *Reptiles and Amphibians of Australia*. Reed New Holland, Sydney.

**Darcovich, K. and O'Meara, J. 2007.** An olympic legacy: green and golden bell frog conservation at Sydney Olympic Park 1993-2006. *Australian Zoologist* (this issue).

**DEC 2005.** Draft Recovery Plan for the Green and Golden Bell Frog (*Litoria aurea*). NSW Department of Environment and Conservation, Hurstville.

**Goldingay, R.L. and Newell, D.A. 2005.** Population estimation of the green and golden bell frog *Litoria aurea* at Port Kembla. *Australian Zoologist* **33**: 210-216.

**Greer, A.E. 1994.** Faunal impact statement for the proposed development works at the Homebush Bay brickpit. Prepared by Australian Museum Business Services for the Property Services Group.

**Hamer, A.J. 2002.** Ecology of the endangered green and golden bell frog *Litoria aurea*: roles of habitat determinants, spatial dynamics, population demography and threatening processes. PhD thesis, University of Newcastle.

**Hamer, A.J., Lane, S.J. and Mahony, M.J. 2002.** Management of freshwater wetlands for the endangered green and golden bell frog (*Litoria aurea*): roles of habitat determinants and space. *Biological Conservation* **106**: 413-424.

**Hamer, A.J., Lane, S.J. and Mahony, M.J. 2003.** Retreat site selection during winter in the Green and Golden Bell Frog, *Litoria aurea* Lesson. *Journal of Herpetology* **37**: 541-545.

**Penman, T.D., Muir, G.W., Magarey, E.R. and Burns, E.J. 2007.** Impact of a chytrid related mortality event on a population of the green and golden bell frog, *Litoria aurea*. *Australian Zoologist* (this issue).

**Perram & Partners Pty. Ltd. 1999.** Statement of environmental effects, Wilson Park Silverwater stage 2 remediation. Prepared for Waste Service NSW on behalf of the Olympic Co-ordination Authority.

**Pyke, G.H. 1995.** Fauna impact statement for proposed development works at the Homebush Bay development area, excluding the brickpit. Prepared by Australian Museum Business Services for the Olympic Co-ordination Authority.

**Pyke, G.H. and White, A.W. 1996.** Habitat requirements for the green and golden bell frog *Litoria aurea*. *Australian Zoologist* **30**: 224-232.

**Pyke, G.H. and White, A.W. 2001.** A review of the biology of the green and golden bell frog *Litoria aurea*. *Australian Zoologist* **31**: 563-598.

**Pyke, G.H., White, A.W., Bishop, P.J. and Waldman, B. 2002.** Habitat-use by the green and golden bell frog *Litoria aurea* in Australia and New Zealand. *Australian Zoologist* **32**: 12-31.

**SOPA and AMBS 2002.** SOPA Frog Management Plan – Management Plan for the Green and Golden Bell Frog at Sydney Olympic Park. Prepared by Australian Museum Business Services and the Sydney Olympic Park Authority.

**White, A.W. and Pyke, G.H. 2008.** Green and Golden Bell Frogs in New South Wales: current status and future prospects. *Australian Zoologist* **34:** 319-333.